

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicants: Grutzediek et al.

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Serial No.: 09/806,224

Examiner: George Fourson

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Group Art Unit: 2823

Title: Method for Producing Transistors

## **Declaration Under 35 U.S.C. 132**

Dr. Michael Rammensee declares:

1. My current position is "process designer" at PREMA Semiconductor .
2. My academic credentials include "Diplom Physiker" and "Dr. Ing." both at the University Erlangen-Nürnberg, Germany.
3. My work experience includes nearly 15 years working in the field of ion implantation in silicon targets. I am familiar with the aspects of implanted doping profiles in semiconductor applications and the associated problems.
4. I am familiar with the teachings of: (a) the Sakurai et al reference (EP-A-0 032 022, FUJITSU LTD, 1981-07-15); (b) Japanese patent (JP 51 073887 A, FUJITSU KABUSHIKI KAISHA, 1976-06-26, application No. 50-364); and (c) the pending U.S. patent application of Dr. Grützediek and Dr. Scheerer (Application No. 09/806,224, filed June 11, 2001, entitled Method For Producing Transistors) including currently pending independent claim 1 thereof.
5. In the Sakurai et al reference (page 2, line 20 – page 4, line 1 and Figs. 2-6), a method is described that had been proposed in a Japanese patent (JP 51 073887 A, FUJITSU KABUSHIKI KAISHA, 1976-06-26). In this method, an ion implantation is done with 1 MeV phosphorous ions at a dosage of  $1 \times 10^{15} / \text{cm}^2$ . With a silicon target, this implantation results in a peak concentration of  $3 \times 10^{19} / \text{cm}^3$  at a depth of about 1.1  $\mu\text{m}$  (see Fig. 1 below: filled squares). The phosphorous concentration declines towards the surface to a value of about  $2 \times 10^{16} / \text{cm}^2$ , which is 20 times higher than the substrate impurity concentration of  $1 \times 10^{15} / \text{cm}^3$  proposed by Sakurai et al (page 7, line 3). Therefore the phosphorous doping overcompensates the p-type substrate doping resulting in a completely n-type doped region between surface and a depth of 1  $\mu\text{m}$ .

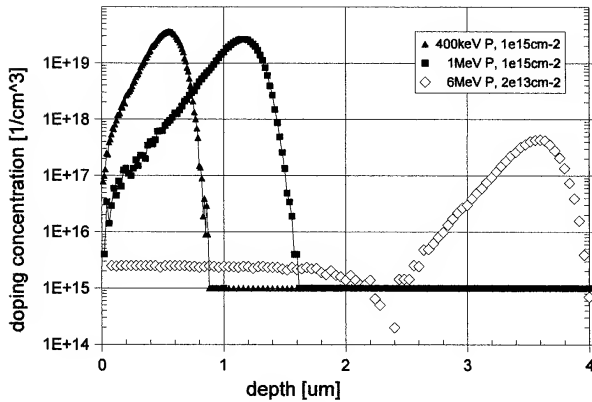


Fig. 1: Doping profiles for three different implantation cases:

- 400 keV phosphorous ions, dosage =  $1 \cdot 10^{15} / \text{cm}^2$ , substrate doping =  $1 \cdot 10^{15} / \text{cm}^3$
- 1 MeV phosphorous ions, dosage =  $1 \cdot 10^{15} / \text{cm}^2$ , substrate doping =  $1 \cdot 10^{15} / \text{cm}^3$
- 6 MeV phosphorous ions, dosage =  $2 \cdot 10^{13} / \text{cm}^2$ , substrate doping =  $2.5 \cdot 10^{15} / \text{cm}^3$

6. Using the above mentioned implantation as a collector, it is not possible to manufacture a NPN bipolar transistor without an additional doping process for the base of the transistor. To keep the original p-type substrate doping at the surface as a base of a NPN transistor it is necessary to increase the energy of the phosphorous ions and/or to decrease the dosage (at the given substrate doping concentration of  $1 \cdot 10^{15} / \text{cm}^3$ ).

7. In contrast to the teachings of above mentioned Sakurai et al reference and Japanese patent, the application of Dr. Grützediek and Dr. Scheerer (Application No. 09/806,224) employs parameters (6 MeV Phosphorous ions, dosage of  $2 \cdot 10^{13} / \text{cm}^2$ ) that are suitable to conserve a typical substrate doping concentration of  $2.5 \cdot 10^{15} / \text{cm}^3$  (specific resistance: 6 Ohm cm) along the surface without overcompensating it (Fig. 1: open rhombs). The p-type doped area is about 2 μm thick, which is enough to use it as a base of a NPN transistor.

8. With an ion energy of 400 keV, instead of 1 MeV, at the same dosage ( $1 \cdot 10^{15} / \text{cm}^2$ ) as proposed by Sakurai et al ( page 7, line 2 – page 8, line 27, and Figs. 8-10) the peak concentration with  $3 \cdot 10^{19} / \text{cm}^3$  can be found at a depth of only 500 nm resulting in a surface concentration of  $2 \cdot 10^{17} / \text{cm}^3$  (Fig. 1: filled triangles). This value is even one order of magnitude higher and thus the conditions to avoid an extra base doping are worse compared to the ion implantation with an energy of 1 MeV.

9. These results can easily be verified with the help of the computer simulation program “SRIM2003”, that can be downloaded from the internet (<http://srim.org>). As a so called “Monte Carlo” program it is able to simulate the ion distribution of all ions of an arbitrary energy in nearly every kind of target material. The result can be displayed graphically (but only on a linear scale) or exported as a text file. It is given in the volume concentration (atoms/cm<sup>3</sup>) per dosage (1/cm<sup>2</sup>). Thus the real concentration in a certain depth can be calculated simply by multiplying the value by the used dosage. In the graphical visualization, the unit is (atoms/cm<sup>3</sup>)/(atoms/cm<sup>2</sup>) and in the text file the unit is atoms/Angstrom/ion. Except a conversion factor these units are equivalent:

$$\text{atoms/Angstrom/ion} = 10^8 * (\text{atoms/cm}^3)/(\text{atoms/cm}^2).$$

The curves of Fig. 1 above are calculated with the help of this program.

10. Therefore, I conclude that the methods of the Sakurai et al reference and Japanese patent do not employ a high enough energy to assure that a weakly doped inner area remains on a surface of a weakly doped substrate when an oppositely doped trough is produced in the substrate by ion implantation.

11. More specifically, I conclude that the above described teachings of the Sakurai et al reference and Japanese patent do not constitute an enabling disclosure for the method of currently pending independent claim 1, namely: A method for producing integrable semiconductor components, in particular transistors, diodes, and logic gates, starting with a weakly p-doped or weakly n-doped semiconductor substrate in the following steps:

application of a mask onto the semiconductor substrate for definition of a window delimited by a peripheral edge;  
production of an n-doped trough in the p-doped semiconductor substrate or p-doped trough in the n-doped semiconductor substrate by means of ion implantation through the mask using a high energy that assures that a weakly p-doped inner area remains on a surface of the p-doped semiconductor substrate or a weakly n-doped inner area remains on a surface of the n-doped semiconductor substrate, wherein a fringe area of the n-doped trough or p-doped trough extends up to the surface of the semiconductor substrate; and  
production of additional n-doped and/or p-doped areas in the p-doped or n-doped inner area and in the fringe area of the n-doped or the p-doped trough that form the structure of the semiconductor component without a step of additional doping of the p-doped inner area or n-doped inner area to prevent turnover of conductivity type.

12. Further, in my opinion, it would not be obvious to derive the method of currently pending independent claim 1 from the teachings of the Sakurai et al reference and Japanese patent.

13. All statements made herein of my own knowledge are true and all statements made on information and belief are believed to be true; and further these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under 18 U.S.C. 1001 and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Respectfully submitted,



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Dr. Michael Rammensee  
Mainz, Germany  
Aug. 30, 2006